Simulation Based Acquisition

Can It Live Up to Its Promises?

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One of the key areas of Acquisition Reform is the increased use of Modeling and Simulation (M&S) in all phases of lifecycle management of defense systems. Dr. Jacques S. Gansler, Under Secretary of Defense (Acquisition & Technology), recently emphasized this policy in his memorandum endorsing a joint DoD-Industry initiative to define a roadmap for Simulation Based Acquisition (SBA).[1]

The move toward SBA was driven primarily by a report commissioned by Dr. Patricia Sanders, Director, Test, Systems Engineering and Evaluation, on the effectiveness of M&S in the acquisition process.[2] A one-year study effort, the report was prepared by a team chartered to visit and obtain data from government and industry on the metrics of successful M&S implementation. Although both generally agreed that substantial benefits may be derived from using M&S in certain areas, very little data exist on the quantifiable benefits.

Although well intentioned, this study falls short of its intended purpose of quantifying the benefits of M&S. The shortcomings of the study can be summarized in one sentence from the summary of the final report: "Substantial evidence has been collected from individual success stories, though the benefits are not readily quantifiable into a general standard."[3]

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The first problem is that the study team used data based on "success stories" to substantiate the conclusions. A scientific assessment should attempt to measure any impacts, positive and negative. Conclusions should then be drawn after evaluating all of the results. Obviously, if the team used only successes to investigate the impact of M&S, then a positive outcome was the only possible result.

The second problem is that the report fails to provide justifiable quantification of the benefits of M&S. This is because the study is composed almost entirely of "apples to oranges" comparisons between different programs. For example, one of the success stories cited in both the study and by Dr. Sanders in her article on M&S[4] states the following: "The working drawings of the CH-53E Super Stallion aircraft's outside contours required 38 Sikorsky draftsmen approximately six months. The same task on the Comanche helicopter program required only one month's effort by one engineer using M&S."[5,6]

This is an impressive figure, but what is the real contribution of M&S to the reduction in time and people? The Super Stallion is much larger physically, which would require more drawings. What is the contribution of Integrated Product Teams and other Acquisition Reform initiatives used in the Comanche program? What is the contribution of more powerful computers? Better M&S certainly played a role, but what was the real impact?

To truly quantify the benefits of using physics-based, integrated M&S, a rigorous study would be needed, comparing different levels of M&S on the same program with all other variables held constant. This would be prohibitively expensive to conduct in the real world on a real program. However, the introduction of an advanced M&S tool as a pilot project into the systems engineering curriculum of the Advanced Program Management Course at the Defense Systems Management College (DSMC) recently provided just such an opportunity.

By providing a physics-based, integrated design and simulation tool to one section while providing the older model to another section for a control group, a comparison of the claims of advanced M&S can be tested. Since this experiment was not conducted on a real DoD acquisition program and the sample size is small, the magnitudes of any differences between the groups would not accurately quantify real development programs. However, it should show if SBA can live up to its claim of better, faster, and cheaper where a physics-based, integrated M&S tool is the only variable.

Project Background

The project used for our evaluation was the "mousetrap" exercise conducted as part of the systems engineering curriculum of DSMC's Advanced Program Management Course. To begin, we divided each section into five contractor teams and provided each team an Operational Requirements Document and a contract with a Statement of Work. Designed as an Advanced Concept Technology Demonstration (ACTD) , the project parallels the Program Definition and Risk Reduction and early Engineering and Manufacturing phases of a full development program.

Guiding student contractor teams through the systems engineering process to an initial design, we then take them into manufacturing and test and evaluation of their prototype. The vehicles are built from a selection of parts provided by the government, with propulsion provided by the springs of one or two standard rattraps. Once the teams reach prototype, the project concludes with a runoff of the prototypes, which must pass the following tests:

- The vehicle must be assembled by one person in less than 12 minutes using only common hand-tools and make a verification run traveling 25 feet in less than seven seconds while remaining within an eight-foot-wide lane (Figure 1).
- The vehicle must travel two round trips of 20 feet each trip delivering two poker chips (simulated ammunition rounds) while remaining within a six-foot-wide-lane in less than two minutes (Figure 2).
- The vehicle must tow a 1.25-pound sled at least five feet while remaining within a four-foot-wide lane (Figure 3).

Best value to the government is defined as the vehicle that can pass all the tests at the lowest unit cost and producibility index (product of the number of types of parts times the total number of parts).

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In setting up the project, we were careful to ensure that the M&S tools were the only variable between the two sections chosen for the evaluation. Air Force Lt. Col. Frank Dibartolomeo and I taught the two sections. Since this was my first time teaching the APMC course, Frank taught the control group while I observed; reversing roles, I then taught the advanced M&S group while Frank watched.

Both groups received the same material and if either group had an advantage, it was the control group since they had a more experienced instructor. Another major difference between this project and the Sanders' study was that we were looking for not only the benefits, but also the drawbacks of advanced M&S. One serious concern was that a standard M&S model might lead the contractor teams to a single solution. Students might be tempted to build what the model told them was the best design without really understanding why. Such a situation might actually have a negative impact on the creativity of the students.

Control Group

The control group received the standard software model used in past APMC courses, which provided students information on one requirement of one test – the five-foot sled pull.

One calculation provides the distance over which the springs will provide power to the drive wheels based on the geometry of the design. This assumes that while towing the sled, the model will coast very little once it exhausts power from the springs.

A second equation provides the distance that a vehicle of a certain weight could travel if all the wind-up energy from the springs could be transformed into linear motion. A third equation provides how many springs the vehicle requires to start moving based on weight and drive train geometry.

Advanced Group

In preparation for the project, we provided the advanced M&S group an integrated design and simulation tool that I had developed specifically for the Stored Energy Ground Vehicle (SEGV) exercise, better known as "mousetrap." Basically, my simulation is a physics-based representation of distance traveled over time using Newton's Laws of Motion. As such, it can predict distances for any of the three tests, with or without the sled attached, when coupled to a spreadsheet containing the data on all the available parts provided in the parts kit.

By integrating the design model with the simulation, the advanced M&S group could vary their designs and see the impact on cost, weight, and producibility index. Students could then carry the weight, geometry, and other design parameters forward into the simulation where they could see the impacts on

FIGURE 1. Assembly Test

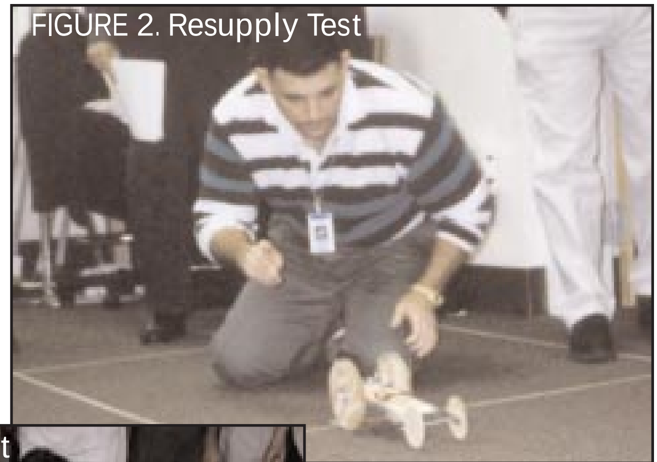
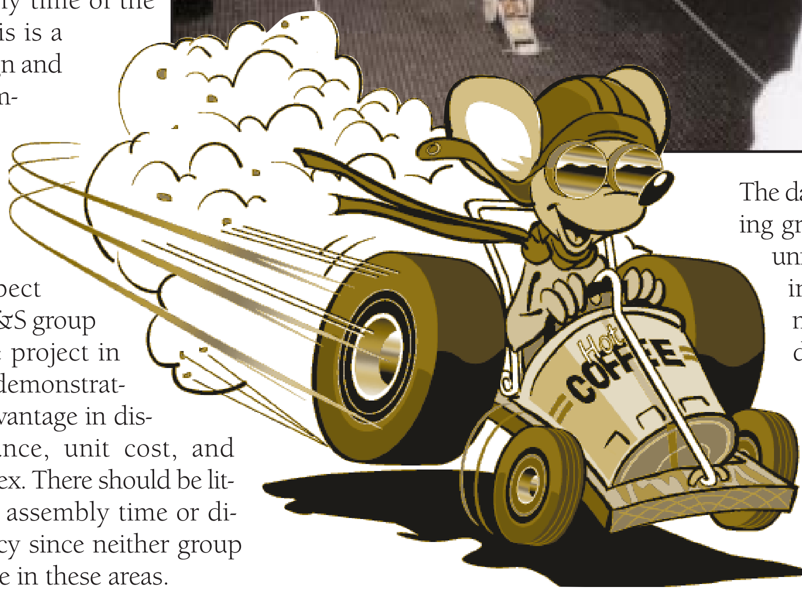


FIGURE 2. Resupply Test

FIGURE 3. Recovery Test

distance performance for all modes of operation. The advanced M&S tool could not predict the directional accuracy of a design since this is primarily a function of manufacturing tolerances. It could also not predict the assembly time of the vehicle since this is a function of design and the person assembling the vehicle.

Based on the claims of SBA, one would expect the advanced M&S group to complete the project in less time while demonstrating a distinct advantage in distance performance, unit cost, and producibility index. There should be little difference in assembly time or directional accuracy since neither group had an advantage in these areas.



Project Results

Typically, we evaluate student progress at three major points during the project. In compiling data for this study, we used results comparing the five contractor teams from each section taken at the following three evaluation points:

Systems Functional Review

The first evaluation is during a Systems Functional Review (SFR). Students must correctly demonstrate and apply the Systems Engineering process in order to arrive at an initial paper design before we issue them a parts kit.

PreliminaryDesign Review

The second evaluation is a Preliminary Design Review (PDR) held at the conclusion of initial prototype testing. Students present the results of their contractor team testing along with a chronology of configuration changes made due to test results.

Final Evaluation

The final evaluation is a runoff held within one week of the PDR.

Initial cost and producibility data provided in Figure 4 show a strong advantage at SFR to the advanced M&S group. Unit cost and producibility index were 20 percent and 56 percent lower respectively. This difference can be attributed to the advanced M&S group looking at three times the number of design concepts in software (Figure 5) to define the key system parameters using the physics-based, integrated M&S tool.

The data validate the SBA claim of achieving greater design maturity with lower unit cost and better producibility during the design phase of development. We perceived no notable difference in schedule between the two groups.

During the build and test phase of the exercise, the control group significantly narrowed the gap in terms of cost and producibility (Figure 4). What the advanced M&S group discovered during initial design work using the better M&S tool, the control group found using the more traditional build-test-fix method. The advanced M&S group still held an advantage in cost and producibility, and now also showed a performance advantage in sled tow range as the result of contractor testing (Figure 6).

One would expect a much higher number of engineering changes from the control group during this period as they caught up using the build-test-fix method. However, as shown in Figure 5,

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this was not the case. In questioning the students on how they proceeded during the test phase, we found that the advanced M&S group continued to use M&S during the test phase. This group, due to their higher-fidelity designs, managed to get their prototypes working early in the test and evaluation phase of the program. However, the teams continued to use M&S and test results to improve their prototypes in the environment of competition.

The introduction of advanced M&S in a competitive environment provided increased performance, lower unit cost, and better producibility. It did not provide any reduction in development cost or schedule for this particular phase. If the cost of the advanced M&S tool could be calculated and included, the development costs of the advanced M&S group might actually be higher.

During the runoff, we conducted the final evaluation of the prototypes (Figure 7). The results show that the advanced M&S group had a clear advantage in vehicle performance, with three of five designs meeting all performance requirements at well below the design-to-cost threshold of $1100. As expected, the advanced M&S group gained no advantage in assembly time or directional accuracy. The control group had a lower average assembly time, while one concept from each group failed a test due to directional accuracy.

The advanced M&S group showed a strong performance advantage in the sled pull test, the most difficult of the distance requirements. During this test the advanced M&S group passed five of five concepts, while the control group passed only two of five.

The fear that advanced M&S might lead students to a common solution proved to be unfounded. As shown in Figure 8, a large variety of designs emerged among the advanced M&S group. Although no metric exists for measuring creativity, it appeared the advanced M&S group exhibited more initiative in their designs. This was probably due to the advanced M&S tool giving them a broader design space to explore in software.

The advanced group also appeared to have more time available for creative exploration in the test and evaluation phase since they were able to get their prototypes working faster due to a better initial design. This was demonstrated by the small difference in engineering changes between the two groups shown in Figure 5. Essentially, the control group was making changes to get their models working, while the advanced M&S group was making changes to be more competitive.

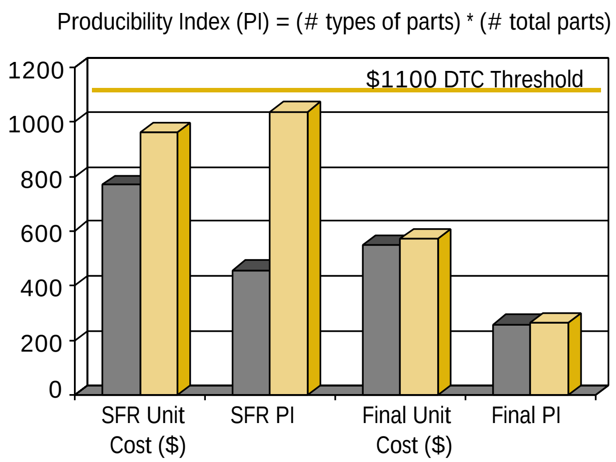

FIGURE 4. Cost/Producibility Comparison

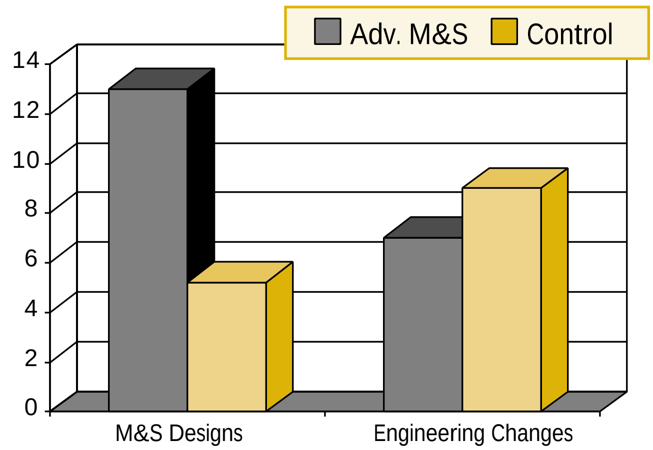

FIGURE 5. Development Comparison

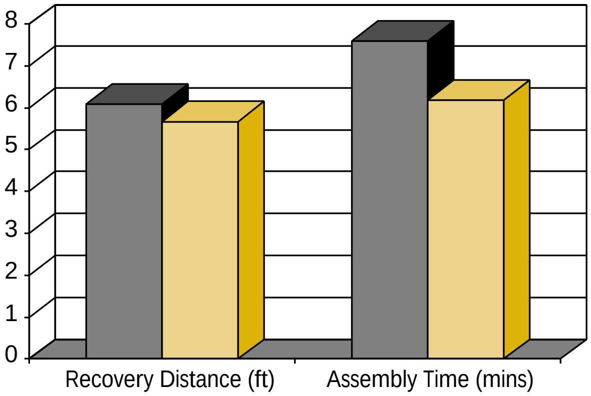

FIGURE 6. Performance Comparison

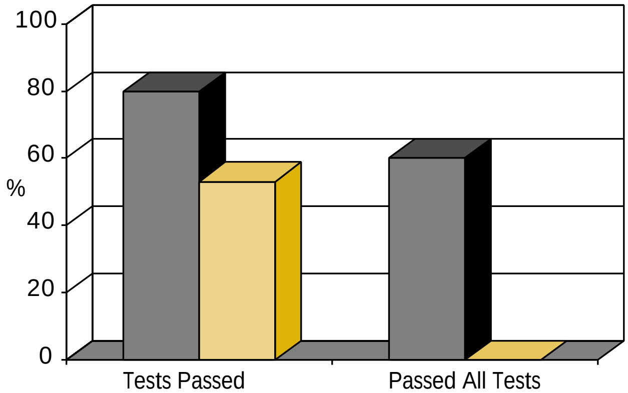

FIGURE 7. Runoff Comparison

Conclusions

FIGURE 8. Advanced M&S Group Concepts

The results of this experiment validate the conclusions of the Sanders' report. When looking at the entire development effort and life-cycle implications, clearly SBA can deliver a product that is better, faster, and cheaper. The fact that this project showed a strong advantage to physics-based, integrated cost/performance models for relatively simple projects demonstrates that SBA can benefit a program regardless of size. The project also shows that the benefits of SBA must be looked at in terms of the entire development effort and the life cycle vice a particular phase.

In our experiment, M&S would likely have increased the cost of this ACTD. However, since we had a much more refined, better performing design with better producibility and lower unit cost, we would expect a shorter Engineering and Manufacturing Development Phase (EMD) and lower production costs had this ACTD transitioned to an acquisition program. Since EMD and production entail far higher expenditures than an ACTD, investment in the advanced M&S tool would have been a prudent decision.

An additional finding of this project is the unexpected results that can occur when different acquisition reform initiatives are combined. Competition is a powerful tool that can motivate a contractor to develop better products at lower cost. SBA has proven its worth in making acquisition better, faster and cheaper. However, when we introduced SBA into a competitive environment, we found that our student contractor teams used M&S to gain a competitive advantage, not to reduce development cost and schedule.

If students in a classroom environment with nothing but pride to motivate them reacted in this manner, in all probability program managers can safely assume that real contractors with millions or even billions of dollars on the line would do the same thing. All of which presupposes the question, "What other acquisition reform initiatives might have complex interactions producing surprise results when combined with each other?"

The results also support Dr. Gansler's policy memorandum encouraging government and industry to move toward SBA. However, the results also show that using advanced M&S in a competitive environment may not save money or reduce the cost of that particular phase of the program. In fact, costs might actually increase in Concept Exploration and Program Definition and Risk Reduction phases. Advanced M&S may fall into the category of requiring an up-front investment to attain large cost and schedule reductions in the long run.

As pointed out in the Sanders' study, large programs have no choice but to commit to M&S up front and to then plan their programs around these investments.[6] But what about smaller programs that do not have the resources to invest

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in advanced M&S? The results of this project appear to validate that these programs can also achieve strong benefits. Where are the resources for smaller programs going to come from?

The Sanders' report also found that currently no vehicle exists to get information on M&S capabilities and facilities to the programs that have the potential to use the assets.[7] IF SBA is to become a reality, resources and support must back it. The future success of SBA will be determined by the answers to these questions as part of the continuing challenge of implementing acquisition reform.

Future of SBA at DSMC

The benefits of SBA are now translated into a better education for APMC students at DSMC. By automating many of the calculations and demonstrating that students can now do much more of the design work through M&S, we added several more functional areas to the SEGV "mousetrap" project.

In addition to the design and simulation models, a life cycle cost model is now integrated into the M&S tool provided the students. The focus of the project is now on practical application of Cost As an Independent Variable, including the Total Cost of Ownership executed in a streamlined acquisition development environment.

IPT and team building exercises conducted in program management, in essence, create the SEGV project teams. Manufacturing processes are now included in the producibility index calculation, better integrating lessons from Manufacturing Management. In addition, we added a Logistics Support Index to emphasize design for supportability from Logistics Management.

Earned Value is now an integral part of the exercise, and Test and Evaluation continues to play a strong role. Further, we are conducting a cost estimating exercise of the SEGV project and introduction of operational test considerations as pilot projects in the ongoing APMC 99-1 class.

Introduction of SBA has allowed students the opportunity to exercise critical thinking skills by making real-world trade-offs among multiple competing functional areas. Moreover, introduction of SBA added no additional hours to the curriculum. By automating and interrelating calculations from different functional areas, SBA has served as an integration tool to improve the entire APMC curriculum.

REFERENCES

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3. Ibid.
4. Ibid.
5. Sanders, Patricia, "Simulation Based Acquisition – An Effective, Affordable Mechanism for Fielding Complex Technologies," *Program Manager,* September-October 1997, p. 75.
6. DTSE&E "Study on the Effectiveness of Modeling and Simulation in the Weapon System Acquisition Process," October 1996.
7. Ibid.

Fred and Ginger? No, but close. It's Coast Guard Capt. Daniel Lloyd and his graceful dance partner, obviously enjoying the entertainment. Assigned to Section C, Lloyd was attending DSMC's Advanced Program Management Course (APMC 98-3) Graduation Dinner-Dance at the Radisson Plaza Hotel, Alexandria, Va., Dec. 16, 1998.

Photo by Richard Mattox